

# **RD 2012-5 Physics**

# **Simulations: Progress Report & Proposal**

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EIC Generic R&D Advisory Committee Meeting  
January 13-14, 2014

# RD 2012-5

- Design and implement event generators for eA
  - ▶ include saturation and non-saturation modes
  - ▶ available for the EIC community
    - ◉ well documented
    - ◉ accessible to everyone
- May 2, 2012: official start of RD 2012-5
  - ▶ Manpower: Tobias Toll (paid out of R&D funds) & TU
- May 2, 2014: official end

# Achievements (I)

## Sartre 1.1

- first event generator for diffractive events in ep **and** eA
- saturation and non-saturation mode
- limited to exclusive vector meson production
- based on impact parameter dependent dipol model(s)
- full nuclear geometry (spherical nuclei) incl. nuclear breakup
- tuned to describe HERA results
- well documented: reference and user guide
- Publications:
  - ▶ physics: Phys. Rev. C87 (2013) 024913
  - ▶ technical: submitted to Comp. Phys. Commun. (arXiv: 1307.8059)
- user community slowly growing (US, China, Europe)
- dedicated web site: <https://code.google.com/p/sartre-mc>

# Achievements (II)

The screenshot shows a web browser window with the address bar displaying 'code.google.com/p/sartre-mc/'. The page title is 'Sartre sartre-mc' and the subtitle is 'Event Generator for Exclusive Diffractive Processes in ep and eA Collisions'. The page has a navigation bar with links for 'Project Home', 'Downloads', 'Source', and 'Administer'. A 'Summary' section is active, showing 'Project Information' and 'Members'. The 'Project Information' section includes 'Stared by 0 users', 'Project feeds', 'Code license' (GNU GPL v3), and 'Labels' (Monte-Carlo, Event-Generator, ep-and-eA-Collisions, Diffraction, Physics, Deep-Inelastic-Scattering, Dipole-Model). The 'Members' section lists 'thomas.ullrich@bnl.gov' and 'tobilibob'. The 'Links' section includes 'External links' and 'Sartre 1.1 Online Documentation'. The main content area is titled 'Sartre' and describes the event generator. It mentions that Sartre is an event generator for exclusive diffractive vector meson production and DVCS in ep and eA collisions based on the dipole model. It describes the process:  $e p \rightarrow e' p' V$  and  $e A \rightarrow e' A' V$  where  $V = J/\psi, \phi, \rho, \gamma$ . Sartre is not a stand-alone program but a set of C++ classes and C functions that form the API. The heart of Sartre is an implementation of the bSat and bCGC dipole models. We extended the models to also describe eA collisions making Sartre the first generator to describe this class of processes. Saturation is introduced in the bSat model through an exponential term in the scattering amplitude. In order to study the impact of saturation on the production cross-section we also construct a non-saturated version of the bSat model, bNonSat, by linearizing the dipole cross-section. Sartre was developed at Brookhaven National Laboratory for studies of electron-ion collisions at future facilities such as EIC (eRHIC/MEIC) and LHeC. Sartre is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation. This program is distributed in the hope that it will be useful, but without any warranty; without even the implied warranty of merchantability or fitness for a particular purpose. See the GNU General Public License for more details. Copyright (C) 2010-2013 Tobias Toll and Thomas Ullrich.

At the bottom of the browser window, there is a status bar showing 'FoxyProxy: Disabled' and weather information: 'Now: -3°C, Fri: 4°C, Sat: 12°C'.

# Achievements (II)

sartre-mc - Event Generator for Exclusive Diffractive Processes in ep and eA Collisions - Google Project Hosting

Sartre Documentation

rhig.physics.yale.edu/~ullrich/sartre-doc/

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## Sartre

Home · Overview · Users Guide · Reference Guide

### Sartre 1.1 Documentation

Getting Started	Sartre Basics	API Reference
<ul style="list-style-type: none"><li>• <a href="#">Overview</a></li><li>• <a href="#">Downloading &amp; Installing Sartre</a></li></ul>	<ul style="list-style-type: none"><li>• <a href="#">Event Generator Users Guide</a></li><li>• <a href="#">Example Program (ep and eA)</a></li><li>• <a href="#">Generating Ultra-Peripheral Collisions</a></li><li>• <a href="#">Event Record</a></li><li>• <a href="#">Table Generator Documentation (experts only)</a></li></ul>	<ul style="list-style-type: none"><li>• <a href="#">Reference Guide</a></li><li>• <a href="#">Runcard Reference</a></li><li>• <a href="#">Table &amp; Table Tools</a></li></ul>
The Physics Behind the Model	Troubleshooting	About Sartre
<ul style="list-style-type: none"><li>• <a href="#">The Dipole Model</a></li><li>• <a href="#">ep and eA Mode</a></li><li>• <a href="#">Generation of Final State Particles</a></li></ul>	<ul style="list-style-type: none"><li>• <a href="#">What's new?</a></li><li>• <a href="#">Known problems</a></li><li>• <a href="#">To-do list</a></li></ul>	<ul style="list-style-type: none"><li>• <a href="#">UML Diagrams</a></li><li>• <a href="#">References, Publications, and Acknowledgments</a></li></ul>

*Last Update: May 29, 2013*

Project Home

Summary People

Project Information

★ Starred by 0

[Project feeds](#)

Code license

[GNU GPL v3](#)

Labels

Monte-Carlo, ep-and-eA-C, Diffraction, P, Deep-Inelastic, Dipole-Mode

Members

[thomas.ullrich](#)

Your role

[Owner](#)

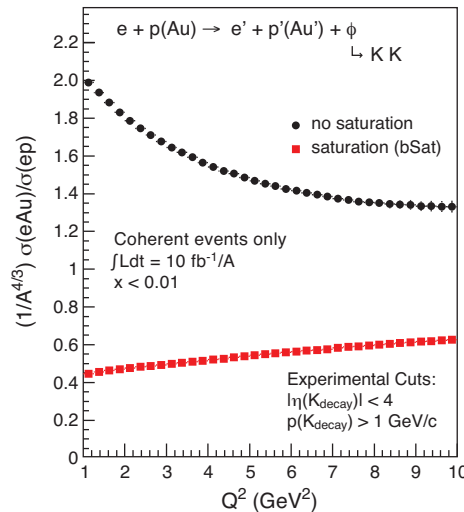
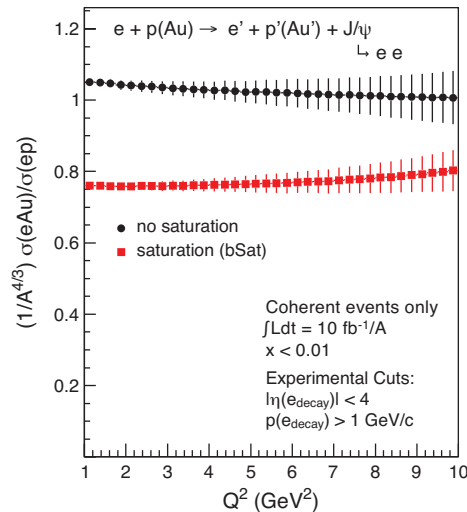
Links

External link

[Sartre 1.1 Overview](#)

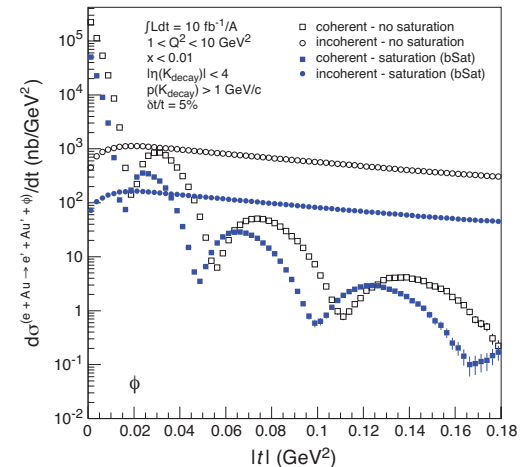
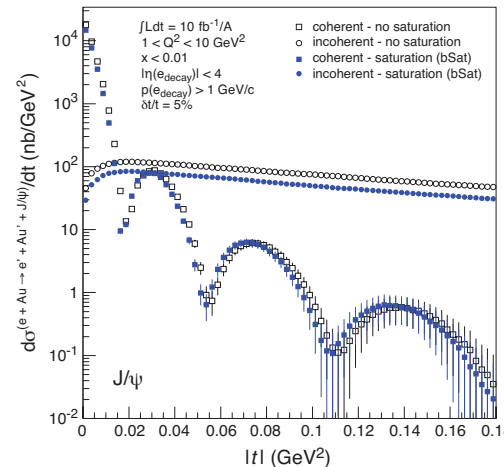
# Achievements (III)

Sartre was extensively used in the realization of the EIC White Paper (arXiv:1212.1701):



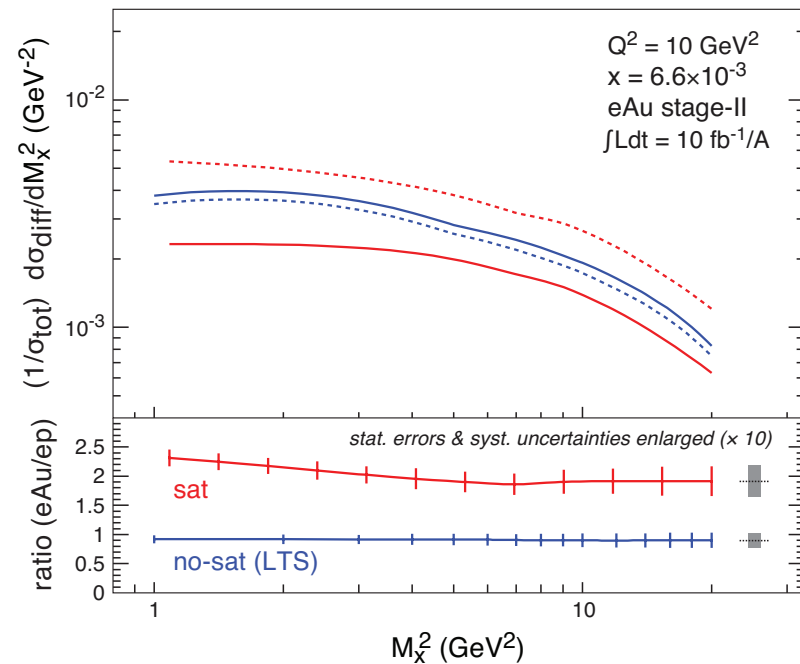
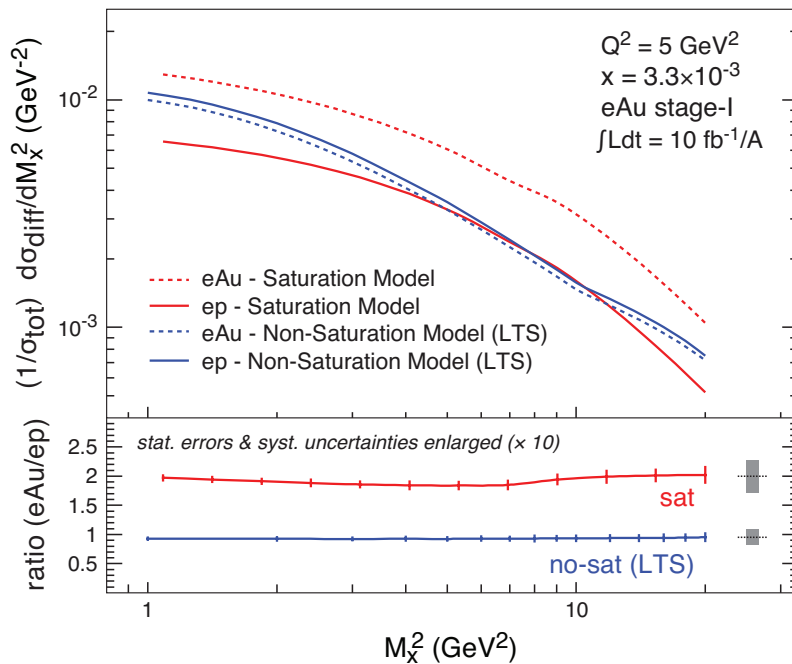
$$\begin{aligned}
 e + p &\rightarrow e' + p' + V \\
 e + Au &\rightarrow e' + Au' + V \\
 \text{where } V &= J/\psi, \phi, \rho, \gamma
 \end{aligned}$$

Exclusive VM production is a key measurement in the EIC eA program



# Limitations of Sartre 1

- Diffraction in eA is of great importance for an EIC
- Current limitation to exclusive production became an issue
- In White Paper inclusive diffractive signatures were provided by colleagues from theory
  - ▶ no possibility to filter through detector simulations
  - ▶ long turn-around times

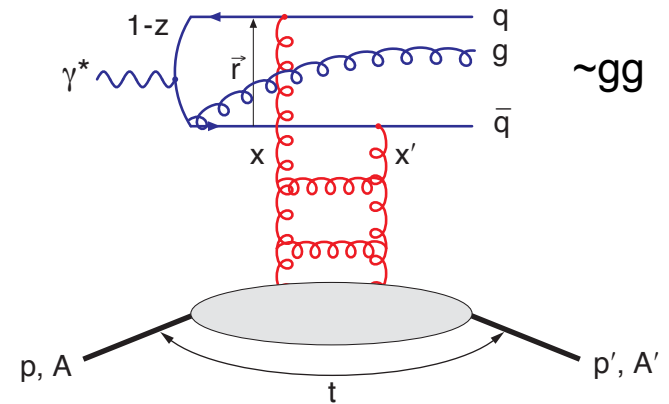
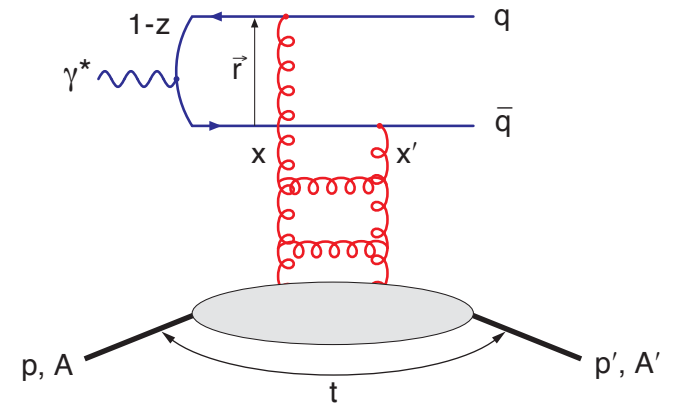
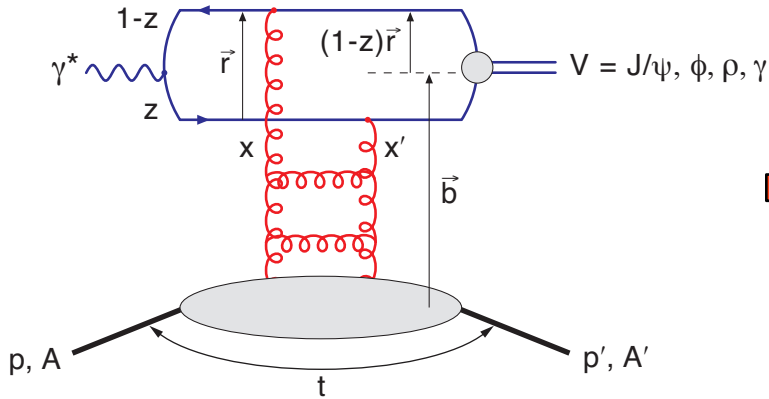


# Overcoming Limitations

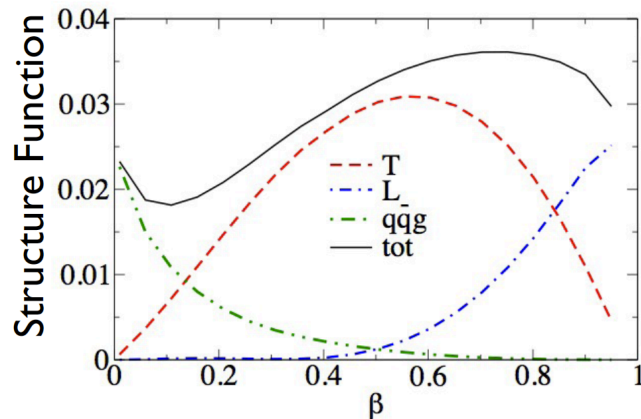
Extending Sartre to  
inclusive diffraction:

$$e + p \rightarrow e' + p' + X$$

$$e + \text{Au} \rightarrow e' + \text{Au}' + X$$



Need to include 2 processes:  $\bar{q}q$  and  $\bar{q}qg$

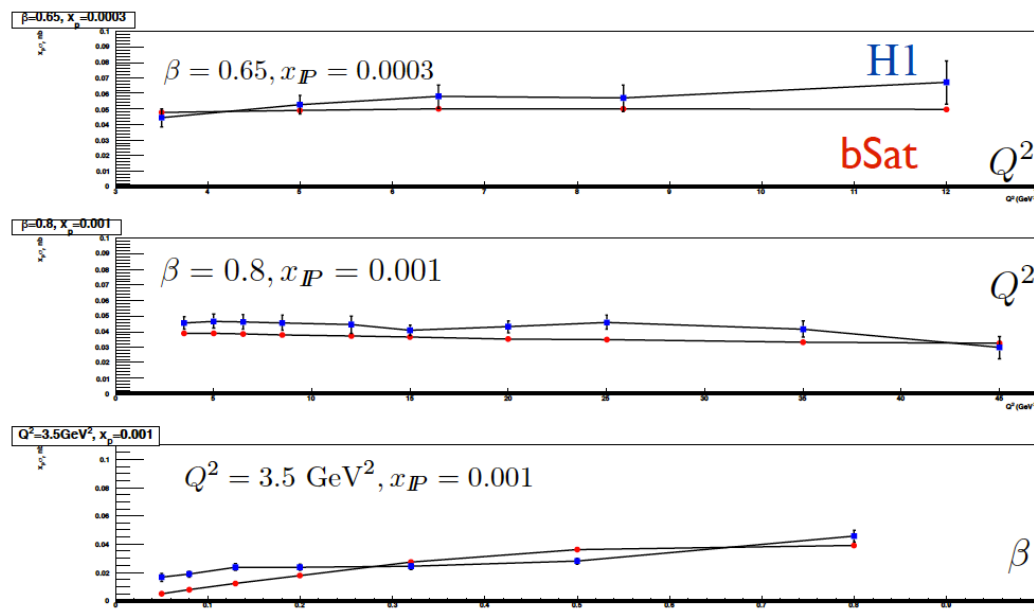




# Achievements (IV)

Fall/Winter 2013: **Start to implement inclusive diffraction**

- Tobias performed all calculation (physics foundation) including the extensions to eA
- Currently implemented in Sartre in “calculation” mode
  - ▶ cross-section are calculated
  - ▶ no event generation yet

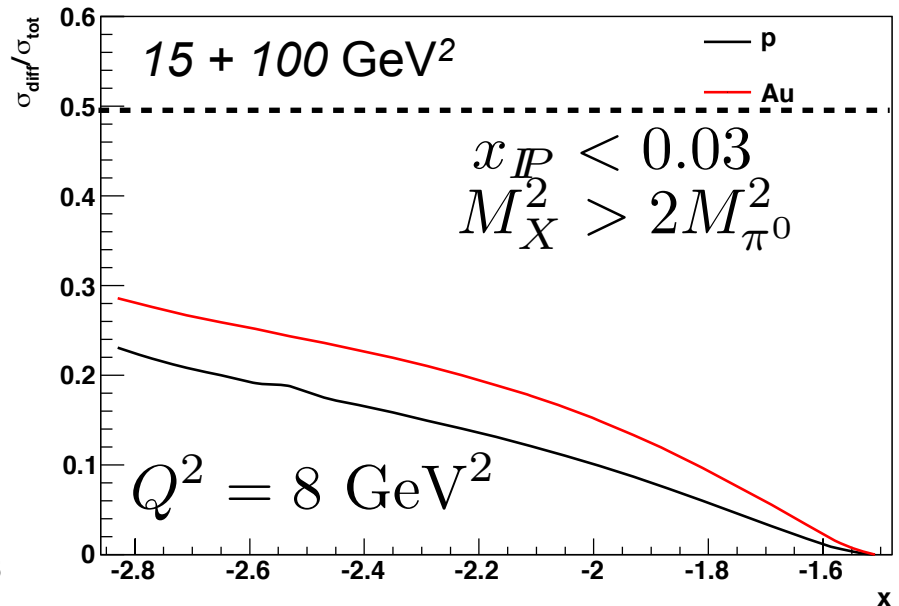
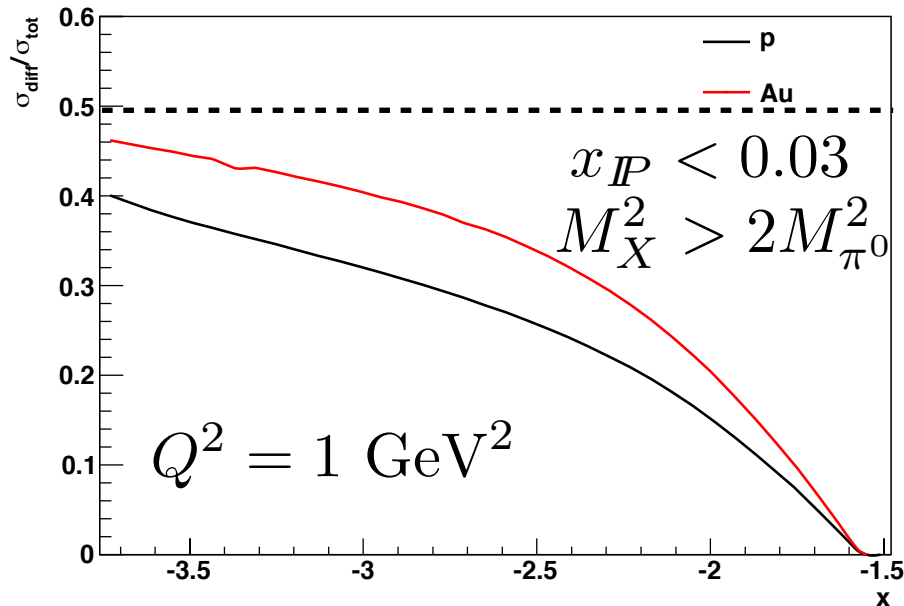


Excellent agreement  
with HERA/H1 data  
on ep mode

# Achievements (V)

## “Inclusive” Sartre

- eA matches well with theory calculation shown in WP
- Now important tool in investigating “critical” measurements



# Sartre: Future Plans

- Redesigning Sartre 1.1 to include inclusive diffraction: **Sartre 2.0**
  - ▶ Changes in class structure needed
  - ▶ Generation of events via sampling from 4D cross-section tables
  - ▶ To generate particles: decay  $\bar{q}q$  and  $\bar{q}qg$  in PYTHIA8
    - ◉ simply linking with PYTHIA8 library will suffice
    - ◉ provides “standard” output used in HEP and NHEP
- Critical Issues
  - ▶ Implementation, testing, and documentation is substantial effort, needs time
  - ▶ Critical ingredient for LRP preparations
- In parallel:
  - ▶ Massive computing efforts on OSG to produce a variety of amplitude tables to extend Sartre 1.1’s reach (Liang Zhang)
    - ◉ cover now LHC energies, more nuclei
  - ▶ Work in progress to extend to deformed nuclei (e.g. U)

# What was not achieved yet?

With Sartre 2 covering all our needs for diffractive events the remaining item is a generator for (deep) inelastic collisions in eA

- Currently:
  - ▶ Hybrid: PYTHIA/EPS09/DPMJet-III (L. Zheng)
  - ▶ contains nuclear geometry, E-loss effects and nuclear breakup
  - ▶ lacks saturation implementation (comparison of sat vs. non-sat scenarios is key for EIC)
- Planned: CASCADE
  - ▶ ep, pp generator for HERA and LHC
  - ▶ CCFM evolution for parton showers
    - ◉ DGLAP for large  $x$ , BFKL for small  $x$
  - ▶ Author: Hannes Jung (DESY)

# CASCADE

- **Can be extended to eA**

- ▶ requires unintegrated PDFs:  $G(x, Q^2, k_T)$
- ▶ saturation: stop/damp evolution for  $k_T < Q_S$

- **To-Do**

- ▶ fit the dipole model to HERA  $F_2$  data with HERA-fitter
- ▶ construct the nuclear scattering amplitude from the resulting fit.
- ▶ construct the nuclear uPDF
- ▶ DID generator: CASCADE + DPMJet-III (nuclear geometry)

- **Reasons for delay**

- ▶ waiting for H. Jung to integrate CASCADE into HERA-fitter....  
(Hannes is hard to come by)
- ▶ inclusive diffraction had higher priority

# Status

	DIS		Diffractive	
	saturated	non-saturated	saturated	non-saturated
exclusive	×	✓	✓	✓
	×	✓		
inclusive	×	✓	(✓)	(✓)
	×	✓		

Know how to solve  
Need uPDF fits

Work in progress

# Proposal

R&D Project ends May 2, 2014

## To Do:

- Sartre 2 (inclusive diffraction)
- Finalize CASCADE

Both not realistically feasible in remaining time

Tobias has likely prospect for junior professorship

- appointment likely not before end of July 2014
- opportune window to complete outstanding To-Do items

## **Request extension of the R&D program by 3 month**

- finish remaining task (needed for LRP preparations)
- bridge Tobias's employment, allowing smooth transition

# Take Away Message

- Exclusive Diffraction (Sartre 1.1) ✓
- Inclusive Diffraction (Sartre 2.0)
  - ▶ mathematical apparatus implemented and tested
  - ▶ generator part to be coded, tested, and documented
- Deep Inelastic Scattering
  - ▶ Hybrid solution for DIS exist and works for non-saturated scenario
  - ▶ CASCADE needs work
    - ◉ path to extend it to eA is well defined
    - ◉ would cover saturated and non-saturated scenarios
- Request extension by 3 month to complete remaining items